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QUANTITATIVE STUDIES ON INSHORE MARINE DIATOMS AND DINOFLAGELLATES COLLECTED IN SOUTHERN CALIFORNIA IN 1924

BY

WINFRED EMORY ALLEN

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INTRODUCTION

Daily collections were taken throughout the year (except Sundays and holidays) at three piers, Scripps Institution of Oceanography at La Jolla, Oceanside, and Pt. Hueneme, as in preceding years (see Allen, 1927*b*, map, p. 32). In addition daily catches were obtained at Pacific Grove by wading out and dipping up water to be poured through the filtration net. This last series was interrupted through July, August, and most of September. The characteristics of the four stations are compared by Dorman (1927, p. 74). Discontinuity renders unsatisfactory attempts at interpretation of conditions at Pacific Grove, especially since catches were very light. Therefore it will not receive much discussion in this report.

At the Scripps Institution pier catches were usually made at about 7:15 A.M. At other stations the time of collecting was more variable but it was usually in the forenoon.

In study of the records, use of the week as the time unit is continued, the average production of the days composing this unit being obtained by mechanical averaging as begun in the latter part of the work on the report for 1922 (Allen, 1927*b*, p. 31).

* This is the sixth of a series of reports dealing with this subject. See Allen, 1922*a* and *b*, 1927*a* and *b*, and Dorman, 1927.

TABLE 1

AVERAGE NUMBERS OF CELLS PER LITER IN SUCCESSIVE SEVEN-DAY PERIODS AT PIERS IN 1924

No. of week	Week ending	Diatoms			Dinoflagellates		
		La Jolla	Oceanside	Hueneme	La Jolla	Oceanside	Hueneme
1	Jan. 7	1,012	3,680	7,456	1,144	640	512
2	14	0	1,056	11,552	572	896	64
3	21	176	32	11,872	176	352	64
4	28	748	480	1,824	264	96	192
5	Feb. 4	6,292	1,952	256	484	96	352
6	11	264	1,664	800	660	544	832
7	18	1,100	1,024	896	704	1,024	480
8	25	660	1,008	6,848	572	1,888	416
9	Mch. 3	19,756	3,328	29,952	880	2,592	352
10	10	1,144	4,992	5,248	792	2,080	288
11	17	484	2,432	15,721	1,452	768	352
12	24	264	1,824	7,328	704	448	576
13	31	1,056	1,200	32,288	220	544	288
14	Apr. 7	572	162,880	2,038,880	220	2,720	320
15	14	4,796	24,448	440,528	836	1,664	1,152
16	21	7,832	9,120	46,736	2,684	1,440	512
17	28	924	896	110,928	4,752	4,512	1,024
18	May 5	308	2,176	8,096	7,524	10,240	2,592
19	12	176	2,496	16,960	6,248	4,800	4,064
20	19	132	3,760	15,640	15,472	24,928	3,440
21	26	220	2,304	28,384	13,263	8,608	1,888
22	June 2	6,864	672	63,920	36,902	18,720	1,200
23	9	5,412	15,800	129,352	35,807	71,744	1,376
24	16	17,966	12,320	171,136	41,270	82,624	3,584
25	23	22,616	21,552	889,600	5,104	5,280	2,560
26	30	11,088	19,544	287,440	2,200	736	3,456
27	July 7	1,216	1,632	61,888	992	800	9,464
28	14	1,120	416	19,216	448	480	6,992
29	21	2,848	1,536	148,840	640	640	4,560
30	28	832	6,720	124,376	672	3,800	18,960
31	Aug. 4	288	8,000	391,104	864	1,568	13,184
32	11	32	2,976	200,608	224	3,456	5,664
33	18	480	608	12,416	768	544	3,648
34	25	220	11,392	59,480	608	1,024	2,240
35	Sept. 1	0	3,640	119,408	768	1,600	4,960
36	8	12,896	6,336	24,368	2,784	576	4,416
37	15	138,816	41,880	76,240	1,184	2,600	3,560
38	22	21,184	22,576	89,216	1,120	1,056	3,392
39	29	480	672	2,496	1,248	640	1,376
40	Oct. 6	256	224	2,496	704	352	1,152
41	13	128	2,688	512	1,632	864	4,288
42	20	3,840	24,832	48,080	896	2,496	4,680
43	27	4,320	39,872	40,000	512	1,888	3,000
44	Nov. 3	34,144	10,240	1,216	384	3,936	1,376
45	10	240,080	4,224	2,816	2,880	3,744	2,720
46	17	10,720	5,632	8,032	3,808	2,272	608
47	24	7,712	20,976	3,264	2,816	928	544
48	Dec. 1	100,288	13,536	2,272	1,796	1,120	352
49	8	2,624	10,624	2,592	1,696	1,280	1,184
50	15	864	1,120	1,248	960	640	480
51	22	512	2,976	768	32	416	352
52	29	32	6,112	352	128	128	192

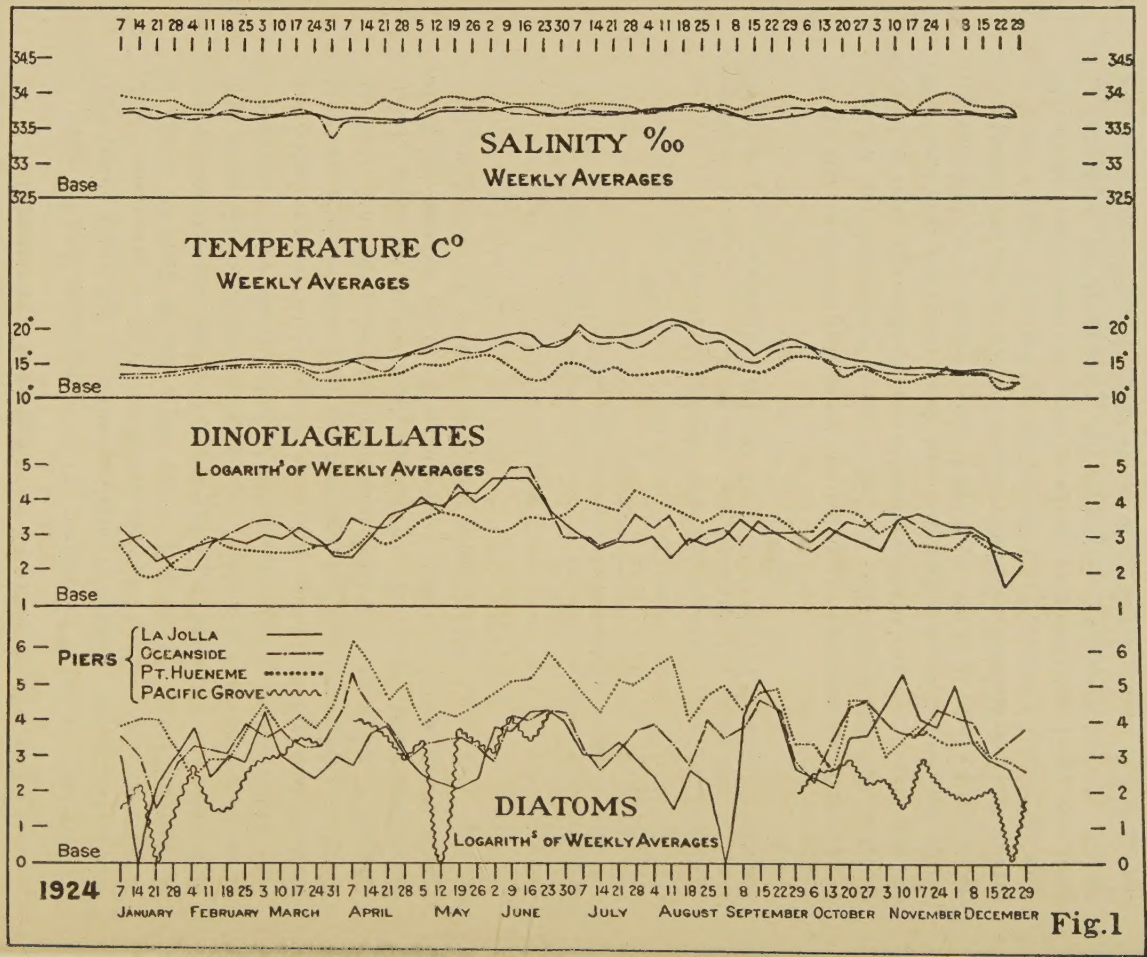
SALINITY ‰
WEEKLY AVERAGES
Base
TEMPERATURE C°
WEEKLY AVERAGES
Base
DINOFLAGELLATES
LOGARITH^S OF WEEKLY AVERAGES
Base
PIERS
LA JOLLA
OCEANSIDE
PT. HUENEME
PACIFIC GROVE
DIATOMS
LOGARITH^S OF WEEKLY AVERAGES
Base
1924
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER

Fig.1

PIER CATCHES, 1924

Geographic Differences in Numbers of Diatoms

Only a brief examination of the records of totals of diatoms for 1924 (table 1 and fig. 1) at the La Jolla, Oceanside, and Pt. Hueneme piers is necessary to show that production at Pt. Hueneme was greatly in excess of that at the other two. Indeed, the total number of diatom cells for the year at Pt. Hueneme (40,760,615) was more than four times as great as the combined totals for the other two piers (8,805,615). On the showing of this particular year one might conclude that the northerly station was representative of a region much more productive than that represented by the two more southerly stations. However, the numbers at La Jolla and Oceanside were only half as great as in the least productive of several preceding years while the number at Pt. Hueneme was about twice as great as the most productive of several preceding years (table 2).

TABLE 2

	Year totals—daily catches of diatom cells—five years					
	1920	1921	1922	1923	1924	Total
La Jolla	18,406,123	22,731,898	14,396,368	8,885,814	4,884,768	69,304,971
Oceanside	.....	13,916,259	7,361,676	10,651,935	3,920,560	.....
Hueneme	11,279,471	6,691,181	7,348,908	21,858,165	40,760,615	87,938,340

In the matter of prominent species of the populations at the three stations the differences seem to be less important although no less striking than the differences in total numbers for the year. At Pt. Hueneme only six species and three catch-all groups reached a leading position for one or more weeks of the year, while at each of the other two stations nineteen species groups reached a leading position in one or more weeks. *Chaetoceras curvisetum* Cl., *C. debile* Cl., *C.* spp., and *C. sociale* Laud. were the groups which produced the large numbers in catches at Pt. Hueneme. All four were represented in the list of leaders for one or more weeks at the other two stations, and it therefore appears that the essential difference in the populations is to be found rather narrowly limited within the genus *Chaetoceras*. In brief, it appears that over several months of the year Pt. Hueneme was favorable for production of a few small species of *Chaetoceras* while La Jolla and Oceanside were not so. However, several species,

notably *Eucampia zoodiacus* Ehr. and *Nitzschia seriata* Cl., also showed much greater numbers at Pt. Hueneme than at the southerly stations and it is not permissible to assume that the geographic differences in conditions were selective amongst common species to any appreciable degree.

Seasonal Differences in Numbers: Diatoms

The most interesting feature in the seasonal distribution is the occurrence of maximum production at La Jolla in the last third of the year (table 1, fig. 1). Both Oceanside and Pt. Hueneme reached highest production in the spring, the season at which that condition is usually to be expected.

Next most interesting is the fact that production was fairly good at Pt. Hueneme over a long period, the last week in March to the last week in September, the weekly averages only once in that time falling below 10,000 cells to the liter (table 1 and fig. 1). That the conditions causing an autumnal maximum at La Jolla were not entirely local is shown by the fact that both Pt. Hueneme and Oceanside showed prominent pulses of production at about the same time. On account of the substantial agreement of the three stations in autumnal trends of production it seems probable that the major peculiarity of La Jolla in 1924 lies in its failure to show sufficient numbers in the spring rather than in its showing of considerable numbers late in the year, although the latter showing is not a point to be neglected.

So far as the incompleteness of the records permits, the showing of the small catches at Pacific Grove has major features resembling those at the other three stations (fig. 1), i.e., an increase in numbers in the first quarter of the year, a considerable drop in the second quarter followed by a rise at midsummer, a drop in the last of the third quarter, and a gradual decrease at the end of the year. Resemblance of the four stations in such gross features is strongly indicative that these changes are essentially seasonal in the sense of close dependence upon distribution of solar energy and conditions incident to its periodicity.

Seasonal Differences in Numbers: Dinoflagellates

Dinoflagellates were found in very few catches and in extremely small numbers at Pacific Grove. They were found in every week of the year at Pt. Hueneme but in much smaller numbers than at La Jolla and Oceanside. The numbers at Oceanside were considerably larger than those at La Jolla. The general indication from this year

is that representation of this group was poor in more northerly sections (table 1 and fig. 1). Maximum numbers were found in June at Oceanside and La Jolla, and about six weeks later at Pt. Hueneme. At all three stations there was a fairly constant trend of increase from the small numbers of winter to the maximum (fig. 1).

"RED WATER"

At La Jolla this maximum was distinguished by the appearance of "red water" and "stinking water" which should have been even more noticeable at Oceanside although not reported there.

On June 1, 1924, red water was noticed at the Scripps Institution pier at about 11 A.M. The color of the water was mostly brownish or dull brick red, also yellowish in thinner spots. The greatest apparent density was at the end of the pier (1,000 feet from shore) at noon. At 5:30 P.M. it was thick in the breakers but not prominent at the end of the pier. Numbers of fish swam through it with apparent indifference. It was the most prominent case of red water seen in the La Jolla region for several years. (The method used with 1924 material, of getting the week average by mixing the daily samples before counting, is not favorable to detailed study of cases like this. Still it was evident that some closing bucket catches made near the bottom [five-meter depth] yielded considerably larger numbers [55,000 per liter] than the surface catches [35,000 per liter] and that *Prorocentrum micans* Ehr. was the main species component at both levels.)

On June 2 red water appeared in the surf at about 2 P.M. Both surface and bottom collections were made at the end of the pier at about 4:30 P.M. at which time the discoloration was greatest near the breakers, except for streaks farther out. Broken by streaks and patches of normal color the discoloration extended as far to seaward as the eye could see from local elevations.

On June 3 red water reached the pier at about 11 A.M., moving directly shoreward. Streaks of reddish water alternated with streaks of almost normal blue. There was a prominent streak of foam on the shoreward edge of the area of red water. On this same date Dr. E. G. Moberg (in charge of the boat doing field work for the Institution) reported "yellow water" ten miles offshore from the pier, the lighter color probably being due to less density of the organisms.

The foregoing description is taken from notes recorded on these dates. No more notes appear in the records for several days although it is my remembrance that the red water was visible every day for the next week. On June 10 the area of discoloration had been reduced

to a patch about three hundred yards wide and a half-mile long, located north of the end of the pier at about 7:15 A.M. It had been seen in a circular form southward from the pier on the preceding evening. A notation of this date says the patch is probably the remains of the red water which first appeared on June 1 and began breaking up a few days later. On June 11 Dr. Moberg reported yellow water at five miles out with an apparent greatest concentration at about three miles out from the pier.

On June 16 the record states that stinking water had become prominent. It is described as having a dirty, greasy look and it attracted attention of people on the beach by its bad odor. A tow-net sample at the end of the pier showed a turbidity in the concentrated sample resembling that of a hay infusion. The matter in the collecting bottle had a bad odor and both the tow net and the hand used in draining it had a strong rancid odor.

The most prominent organism in the red water was *Prorocentrum micans* Ehr. while the one most prominent in the stinking water was a tintinnid, probably a species of *Cyttarocyclus*. However, there were considerable numbers of peridinians and a few diatoms in the stinking water. Dr. Moberg said that at this time the area of water with bad odor extended as far as five miles offshore. At no time was there any recognized evidence of injury to animals such as is sometimes reported after occurrence of red water.

This case of red water was not so conspicuous as some of earlier dates (Torrey, 1902, Kofoid, 1911, Allen, 1921), but there were resemblances; e.g., although more constantly visible near shore it was observed as far as ten miles out to sea, its general appearance at the surface of the water was streaky or patchy, and it was followed by stinking water.

It differed distinctly from these earlier cases in identity of the leading species components, the earlier cases having been due to *Gonyaulax polyedra* Stein. However, from time to time since 1917, catches have been made from small areas of red water found offshore, in all of which *Prorocentrum micans* Ehr. was the leading component just as it was in the 1924 case. In 1924 it also differed in not being followed by any apparent decimation of the animal population such as had occurred in the other cases.

Superficially, this case of red water, like some others, seems to be sporadic in character, but this appearance does not agree with the fact of its representing a culmination of a gradual increase in numbers (fig. 1) from the early part of the year. If the unusual color and the bad odor of the water had not attracted attention the increased numbers in catches in June might have been considered as nothing

more than the climax of a series of changes in productivity related to the change in the seasons. This fact leads to the thought that many natural phenomena appearing to be sporadic in character have that appearance solely because of insufficient extent and continuity of observation.

The red water of 1924 probably covered at its maximum stage an area thirty or forty miles in length and at least ten miles wide at one time and place. The red water of 1917 (Allen, 1921) received very limited observation so it is not known what relation the small patch (*Prorocentrum*) observed twelve miles off San Pedro on June 4, bore to the lethal waters (*Gonyaulax*) observed in the vicinity of Santa Barbara in September. None of these cases were at all comparable in extent and visible influence with the red water of 1901, lethal in mid-July over two hundred miles of coast line from San Diego to Santa Barbara, and visible near San Pedro as late as September 1, nearly two months after its first discovery.

These cases of red water are important because they afford the only known instances in the southern California region of conditions open to ocular inspection over areas comparable in extent with the slopes and plains of the land. In them was evidence accessible to all men of good vision, trained or untrained, showing that life in the sea is not uniformly distributed through space and time, that it does not run a smooth course, that the superabundance of an insignificant looking form may be highly dangerous to its neighbors, and that excessive numbers may be as highly destructive to the members of the abnormally exuberant species as they are to any of its associates by contiguity.

Torrey (1902) and Kofoid (1911) both write confidently of the origin of "stinking water" from decadent "red water." The conditions of the 1924 occurrence seem to point as strongly as those of Santa Barbara in 1917 and the whole coast of southern California in 1901 in favor of the suggestion that death and decay of the superabundant organisms caused stinking water. However, the fact of causal connection has not yet been established by direct investigation and carefully correlated evidence and the mode of connection is still further removed from actual demonstration. I have a strong impression that this series of transitions in a visible population affords a highly promising point for attack in investigating certain types (particularly chemical) of reciprocal influences amongst organisms in a state of nature.

After the summer maximum characterized by its display of red water, the dinoflagellates did not contribute much to the numbers of microplankton organisms.

Temperatures and Salinities

Differences in temperatures and salinities between Pt. Hueneme and the two more southerly stations, Oceanside and La Jolla, were distinct through most of the year (fig. 1). Temperatures were uniformly lower and salinities almost uniformly higher at Pt. Hueneme. There were no distinct seasonal differences in temperatures at Pt. Hueneme although both the other stations showed a considerable rise in temperature through the summer. If it were not for the April maximum in numbers of diatoms at Pt. Hueneme one might be tempted to think that the strong productivity of the summer was directly correlated with the low temperatures there. This correlation may exist but it is not clearly shown that it does.

Summary

1. The great excess in numbers of diatoms at Pt. Hueneme as compared with other stations is especially notable.

2. The autumnal maximum of diatoms at La Jolla is exceptional.

3. Dinoflagellates were so numerous at La Jolla in June that there was distinct discoloration of the water. They were collected in larger numbers at Oceanside but no mention was made of discoloration there.

4. There was notable constancy of higher salinities and lower temperatures at Pt. Hueneme as compared with Oceanside and La Jolla.

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